SCIENCE

FRIDAY, AUGUST 15, 1919

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MSS. intended for publication and books, etc., intended for review should be sent to The Editor of Science, Garrison-on-Hudson, N. Y.

THE RESPONSIBILITIES OF THE SCIENTIST[1]

LITTLE more than two years ago, the American man of science was in his laboratory, busy with the problems of research. The possibilities of progress were never greater, and the obligation to exceptional effort, for the purpose of assisting to retrieve some of the heavy losses suffered by science through the war, was constantly before him. But the perennial attractions of research and the strongest desire to advance science were insufficient to hold his attention. He watched with indignation the piratical attacks of the submarine, the brutal invasion of provinces and states, the unspeakable horrors of the German advance. Undeceived by specious pleas for peace, he recognized the clear duty of the United States, and chafed at repeated delays when quick and determined action would have saved countless lives. And when, at last, we entered the war, he eagerly grasped any opportunity for service that came to him. Sometimes the opportunity did not come, and he then accepted the more difficult, but no less obvious, duty to persevere in his researches and thus to preserve the continuity of scientific progress.

The experience during the war of the man of science has sometimes been confusing, and it is possible that his responsibilities on the return of peace will not always be clearly recognized. Men who have previously devoted their lives to the advancement of knowledge have suddenly been called upon to solve practical problems, of the greatest military or industrial importance. In attacking these new questions, they have shown remarkable powers of adaptation, and surprise has often been

[1] Read before the Pacific Division of the American Association for the Advancement of Science, as a part of a symposium on "Scientific Education in a Democracy."

expressed that they could turn so readily from fundamental researches for the increase of knowledge to the most intensely practical undertakings.

But a moment's consideration will show how easily the change has been effected. An eminent physicist develops a new range-finder, which is adopted by the navy because of its superiority to any existing instrument. But what could be less surprising, in view of his life-long success in devising new optical instruments for physical research?

Several men of science, working in close cooperation, effect great improvements in a device for accurately locating invisible submarines, even when completely at rest and emitting no sound. But the fundamental principles and methods involved in this war research are precisely the same that these investigators have employed for years in their electrical and astronomical investigations. And so I might go on, mentioning scores of important war services performed by physicists, mathematicians, chemists, astronomers, meteorologists, geologists, botanists, zoologists, bacteriologists, anthropologists, psychologists and investigators dealing with every branch of science, whose previous efforts have been wholly devoted to the advancement of knowledge.

Some of these men, when seriously reflecting upon their responsibilities at the close of the war, have hesitated to return to their old tasks. They have often been applauded, by those who know nothing of research, for their newly-discovered ability to accomplish "practical" results, and to contribute in this obvious way to the public welfare. Or they have been offered by the industries salaries far in excess of those they receive from the university or technical school. Which way shall they turn? How may they best serve the world?

These questions have been clearly answered long since, not only by students of science, but no less emphatically by great leaders of industry. No American engineer stands higher than J. J. Carty, vice-president of the American Telephone and Telegraph Company, recently colonel in the Signal Corps, in charge of our lines of communication in Europe. In his address as president of the American Institute of Electrical Engineers, after showing that the industries, through self-interest, will provide amply for industrial research, Colonel Carty dwells on the importance of fundamental researches in science, and remarks:

> By every means in our power, therefore, let us show our appreciation of pure science and let us forward the work of the pure scientists, for they are the advance guard of civilization. They point the way which we must follow. Let us arouse the people of our country to the wonderful possibilities of scientific discovery and to the responsibility to support it which rests upon them, and I am sure they will respond generously and effectively.

Or take the word of W. R. Whitney, director of the great industrial laboratory of the General Electric Company:

> Necessity is not the mother of invention; knowledge and experiment are its parents. This is clearly seen in the case of many industrial discoveries; high-speed cutting tools were not a necessity which preceded, but an application which followed, the discovery of the properties of tungsten-chromium-iron alloys; so, too, the use of titanium in arc lamps and of vanadium in steel were sequels to the industrial preparation of these metals, and not discoveries made by sheer force of necessity.

Or remember the statement of Huxley:

> I weigh my words when I say that if the nation could purchase a potential Watt, or Davy, or Faraday, at the cost of a hundred thousand pounds down, he would be dirt-cheap at the money. It is a mere commonplace and everyday piece of knowledge that what these men did has produced untold millions of wealth, in the narrowest economical sense of the word.

How true this is, how directly the greatest practical advances are dependent upon researches made solely for the advancement of knowledge, without any thought of immediate application, is well illustrated in the case of wireless telegraphy. The existence of waves in the ether, much longer than those that give the impression of light, but traveling with the same velocity, was first definitely shown by Maxwell, in his purely mathematical investigations on the electromagnetic theory of light. For twenty years these waves were known only in his equations, but in 1888 Hertz found

that they were actually emitted by a spark in his laboratory, and could easily be detected across the room and at greater distances. This made wireless telegraphy possible. Afterwards it was only a question of perfecting the transmitting and receiving devices in order to increase their range. This was no light task, and we owe much to Marconi and others for accomplishing it. But it is plain that wireless telegraphy could not have been even imagined before the discovery of electric waves in the ether by Maxwell and Hertz.

Some advances in science are less direct in their application, but even more significant. Of what benefit to the world is astronomy, the oldest of the sciences? I need not dwell on its obvious applications in the measurement of time, in accurate surveys of the earth's surface, in the determination of positions at sea. These uses render astronomy invaluable, but they do not represent its greatest contribution to the world.

To appreciate this, we must turn to the pages of Henri Poincaré, in his little book on "The Value of Science." The basis of scientific progress is law, and we owe the conquest of law to astronomy. Where would our modern civilization be, asks Poincaré, if the earth, like Jupiter, had always been enveloped by clouds? Our remote ancestors were creatures of superstition, surrounded by mysteries, startled at every display of incomprehensible forces, accustomed to attribute all natural phenomena to the caprice of good and evil spirits. To-day we no longer implore the aid of nature: we command her to do our bidding, because we have learned some of her secrets, and are constantly solving others. We command her in the name of laws which she can not repudiate, because they are her own. Recognizing, as we do, the unchangeable basis of these laws, we do not foolishly demand that they be changed, but submit ourselves to them, and utilize them to the advantage of mankind.

Astronomy taught us the existence of the laws of nature. The Chaldeans, first to observe the heavens attentively, perceived harmony of motion and sequence of phenomena. Day and night, the round of the seasons, the phases of the moon, the periodic wanderings of the planets, held their attention and encouraged their study. Their work was continued by the Greek astronomers, who discovered rule after rule with the simple instruments at their command. Tycho Brahe, Copernicus, Kepler and Galileo pushed forward the advance at an accelerating rate, until Newton finally announced the oldest, the most accurate, the simplest and the most general of all natural laws.

Encouraged by these never-ending successes, students turned their attention to the phenomena of the earth's surface, and found in their apparent disorder the same harmony and the same reign of law. But the infinite variety of nature, the conflict of forces, and the extreme complexity of terrestrial phenomena would have greatly delayed progress if the simple and easily-discovered rules of the heavens had not pointed the way. Faced with discouragement, the physicist or the zoologist could fall back upon the assurance, which astronomy had repeatedly afforded, that nature does obey laws. Their task, therefore, was to discover these laws, and to persist in their endeavors until the difficulties had been overcome.

I wish that time permitted me to follow Poincaré further and to show how the world's debt to astronomy rests not merely upon her initial discovery of natural laws, but also upon her proof that these laws, once accurately determined, are unchangeable through the centuries, and that they apply in every part of the visible universe. I might also show how Copernicus and Galileo, when they demonstrated that the sun and not the earth is at the center of our system, smashed into fragments the medieval mode of thought, and reestablished the true methods of science, previously used in more restricted form by the Greeks. If it were still maintained that the task of astronomy has been accomplished, I might point out that only yesterday it demonstrated that the elements and some of the compounds of the chemist are not confined to the earth, but are present in the most distant stars, and that the latest developments of electrical theory and the most recent investigations on the nature of matter are tested by

observations of the sun, stars, and nebulæ. And I might add, if I thought it would strengthen the argument, that the light gas helium, which was first produced on a large scale during the war, and would have rendered the great bombing dirigibles of the Allies practically safe over Berlin, because of its non-inflammable and non-explosive character, was discovered in the sun a quarter of a century before it was found on the earth.

But I have said enough, I hope, to convince you that astronomy has been of real service to the world, and that its study should be continued, especially in this prolific period when our understanding of the extent and nature of the universe is advancing more rapidly than ever before. And if the present duty of the astronomer to advance the knowledge of his science is plain, that of the investigator in every other field is equally so. He should go back to research, with new vigor and redoubled energy, without troubling himself for a moment with the question of immediate practical return.

Industrial research must be enormously developed in the United States, and the old distinction between pure and applied science must be swept away.[2] But once awakened, as they already are, the industries may be trusted to follow the example of the duPont Company, which began with five research chemists in 1902, and spent three millions in their research laboratories during 1918. The task of the educational institution and of the private research foundation under such conditions is a tremendous one. They must not only develop investigators capable of doing the work of the industries, as the German universities have done for so many years; they must also push forward, on a far greater scale than ever before, their researches for the advancement of knowledge. Only thus can the highest advantage of science and industry, the chief interests of public welfare, and the greatest national progress, be attained.

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[2] See Hale, "The National Engineering Societies and the National Research Council."

THE PRESS AS AN INTERMEDIARY BETWEEN THE INVESTIGATOR AND THE PUBLIC[1]

It it with some diffidence that as a rank amateur I accept the invitation of so learned a body to make any suggestions even upon that branch of your work upon which we are all amateurs. But perhaps just because it is a question, not of the discovery of truth, but of the promulgation of that truth to the unprofessional public, there may be some advantage in approaching it from the standpoint of a mere member of that public.

I am not sure that there is unanimous or immediate consent to the doctrine that any merely popular intermediary between the investigator and the public is even desirable. Certainly there has in the past been enough of aloofness on both sides, for which neither side has been guiltless. Even where science has not inherited the jealous exclusiveness of a professional guild, the original investigator had had temptation enough to remain aloof from the public. If his discoveries were of any practical use, others would advertise them soon enough. If they merely opened wider the portals of truth, the public was little interested, and there would be time enough for its enlightenment when the ponderous monograph became a sentence or a footnote in the elementary text-books. Besides, it seemed so hopeless to give the public what it ought to have, and so worse than useless to give it what it wanted. The whole mental viewpoints were different. The scientist is cautious, accurate and impersonal. He uses his imagination, not to jump at conclusions, but as a guide to experiment and investigation. He hesitates to announce a discovery until he has fully verified it, and then he limits himself strictly to the one step he has taken into the Unknown, and avoids flights of fancy into its speculative possibilities. If his knowledge is fragmentary, he refuses to fill out its gaps, and he is resolutely non-committal on what he does not know. He cultivates an imper-

[1] Read before the Pasadena Division of the American Association for the Advancement of Science, June 20, 1919.